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SNOW SURVEYING

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SNOW SURVEYING

By JAMES C. MARR, *irrigation engineer, Division of Irrigation, Soil Conservation Service* [1]

CONTENTS

	Page
Introduction	2
How water content of snow is determined	2
How reliable measurements are obtained	3
When snow surveys are made	4
How forecasts are made	5
Uses for water-supply forecasts	6
Irrigation	6
Flood control	6
Water supplies for operation of hydroelectric plants	7
Watershed protection	8
Stock water	8
Municipal water supply	8
Estimates of snow load	8
Farm-loan servicing	8
Crop estimates	8
Mining operations	9
Care and protection of wildlife	9
Industry and commerce	9
Snow-sampling equipment	9
Federal equipment	9
Mount Rose equipment	11
Utah equipment	11
Tools	11
Care of equipment	12
Keeping tube free of dents	12
Repairing and replacing the cutter	12
Keeping threaded duraluminum couplings from seizing	12
Using spanner wrenches for uncoupling tubes	13
Avoiding the bending of tubes	13
Keeping sampler coated with paraffin or shellac	13
Keeping balance accurate	14
Cleaning and drying equipment after use	14
Carrying equipment in case or with harness	14
Snow-sampling procedure	15
Acquaintance with location of snow course	15
Locating the specified sampling points	15
Assembling the sampler	16
Cutting a true core of the snow cover	16
Snow-sampling procedure—Continued.	Page
Weighing the empty sampler	17
Measuring the snow depth	19
Retaining the core while withdrawing the sampler	19
Measuring the length of core	19
Weighing the core	19
Dumping the core	20
Sources of error and their elimination	20
Procedure under special conditions	21
Recording the notes	22
Field-office procedure	23
Computing field notes	23
Sample field notes	24
Transcribing field notes	24
Reporting by telegraph	25
Reporting by radio and telephone	25
Forwarding original field notes	25
Retaining copy of notes at station of chief snow surveyor	25
Reporting when there is no snow	25
Improvement and maintenance of snow courses and facilities for snow surveys	26
Safeguarding desirable features of snow courses	26
Improving ground conditions for snow sampling	26
Better marking of courses	26
Making trails safer for travel	27
Improving and supplementing shelter cabins	27
Equipping and stocking shelter cabins	28
Winter travel	29
Selection and use of skis and snowshoes	29
Suggestions on the care of snowshoes and skis	31
Crew requirements	32
Dress	32
Travel kit	33
First aid	33
General health and advisability of physical examination	33
First-aid kit and first-aid supplies	34
First-aid procedure in certain emergencies	35
Conclusion	44

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INTRODUCTION

The snow that accumulates at high elevations in the Western States is a natural storage reservoir from which the major part of the water supply for these States is derived. Forecasting the water supply is a service of interest to farmers, ranchers, shippers, bankers, and agencies concerned with power production, water supplies, and flood control. The amount of run-off from a drainage basin cannot be predicted from meteorological measurements of the snow that falls, but dependable estimates of the run-off can be made from measurements of the snow pack after the accumulation of snow has reached its maximum if the snow courses established for the area yield reliable samples. For more than 30 years forecasts have been made on the data obtained by making measurements of the water content of the snow that accumulates during the winter. The accepted method of making these measurements is termed "snow surveying."

Up to 1935 forecasts based on snow surveys had been successfully made for most of the principal watersheds in Nevada, Utah, and California, and some forecasting had been done in Oregon, Idaho, Wyoming, and Washington. Since July 1, 1935, there has been under way a program authorized by the Federal Government to extend and unify the activity throughout 11 Western States, including those named above and Montana, New Mexico, Colorado, and Arizona. The organization set up to carry on the work is highly cooperative,[2] particularly in the conduct of the winter field work. The services of a large force of responsible and able-bodied men, estimated at 2,000, are required to make the surveys simultaneously at widely separated points over a vast region at designated times during the winter months. This publication is written in furtherance of this program and is intended primarily to answer questions that may arise in the minds of the men who make the snow surveys.

HOW WATER CONTENT OF SNOW IS DETERMINED

The approved procedure for determining the water content of snow consists essentially in procuring cores of small diameter vertically from the snow cover at designated points along a snow course and weighing them. A metal tube, designed especially for this purpose, is used to obtain the cores. The diameter of the snow core (1.485 inches [3]) is such that its weight in ounces is equivalent to inches of water; that is, a core of snow weighing 1 ounce represents 1 inch of water in a cylinder of the same diameter. Thus snow depth is quickly

[2] The Soil Conservation Service on July 1, 1939, took over the irrigation investigations, including snow survey work, formerly conducted by the Bureau of Agricultural Engineering. The Weather Bureau is also charged with activities in snow surveying and river and flood forecasting, and much of this work is carried on cooperatively by the Bureau and the Soil Conservation Service. Other important cooperators in the snow-survey work include the office of State engineer in six States, three State agricultural experiment stations, several municipalities, numerous irrigation enterprises, most of the large power companies, and the following Federal agencies: Forest Service, Bureau of Reclamation, National Park Service, Bureau of Biological Survey, Corps of Engineers of the U. S. Army, Geological Survey, and Office of Indian Affairs. The Water Rights Branch of the Department of Lands, British Columbia, sponsors a supporting snow-survey program on the Columbia River drainage basin in Canada, and through exchange the data for this international stream are made complete for both countries.

[3] The diameter is 1½ inches if Mount Rose snow samplers are used. In this sampler the balance is especially calibrated to read, in inches depth of water. The Federal Mount Rose and Utah Mount Rose samplers cut the 1.485-inch-diameter snow cores. (See description of these instruments on pp. 9–11.)

and accurately converted into the more significant figure, water depth, simply by weighing the cores; and a measurement made in this manner at a properly located sampling point discloses the depth of water in the snow mantle.

The accuracy and rapidity with which the water content of snow is measured with standard snow-sampling equipment give this procedure a practical advantage over other known methods of making such measurements, particularly when they must be made in high, isolated mountain areas during the winter.

Obviously, it is difficult from observations of snow depth made in snow-stake readings to estimate accurately the water content of the snow cover, especially when it is deep and laminated. The observed depth of snow, alone, is inadequate as a basis for forecasting run-off.

The arduous and time-consuming practice of gathering samples of the snow cover and melting them to determine water content is also made unnecessary by the quicker, easier, and more accurate way in which the measurements are obtained with standard snow-sampling equipment.

HOW RELIABLE MEASUREMENTS ARE OBTAINED

If a reliable forecast is to be made from the measurement of the water content of the snow, certain requirements must be observed.

1. Measurements must be made at elevations where little or no melting occurs until after April 1. The snow surveyor may have to travel far into the mountains to reach elevations where snow will not have melted materially by the time of the April survey during such years as 1934. There are other reasons for placing snow courses high in the mountains, but this one alone justifies the difficult winter trips sometimes required to reach these high elevations.

2. The snow course must be sufficiently accessible to insure continuity of the surveys. Great care should be exercised in finding the most accessible location when a snow course is established, especially if it is a high one. If, after a course has been established, another location just as good is found, it is not advisable to change the location because the change destroys the continuity of the records on which the forecasting is based.

3. Measurements must be made at a sufficient number of fixed points on an established marked course to insure that the average of the measurements will not be unduly affected by drifting or wind-swept snow. Snow surveyors will find little similarity in the design of snow courses, and many wonder why some are longer and call for more measurements than others. Each course is planned definitely to permit a group of measurements, the average of which will represent the snow cover at the given elevation and exposure. The topography and the presence or absence of forest cover account for wide variations in the design of courses.

Assume that an open place is found in the forest and so nestled among hills as to be protected from high winds and large enough that snow may fall to the ground without being intercepted. If the snow falls and lies uniformly over this area, comparatively few measurements, made either as a group in one space or separately in several adjacent spaces, will yield the desired record. If the open space is

large and of a shape that might permit the snow to shift within it, the only sure plan to follow is to make a series of measurements along lines that form a cross, or an L, or are otherwise so arranged that the average of the measurements will represent the depth of snow cover within the area.

If protection from wind is altogether lacking and the course must be in the open, the measurements should be taken over an area of at least one-half square mile. A small area cannot be selected with assurance that the average of any number of measurements made within it will indicate the average depth of snow cover for the locality. Since sufficient knowledge of the unobstructed tendency of the snow to drift and the direction in which drifting will occur is lacking, it is expedient to provide for an extensive survey having long courses and a large number of measurements. Once the prevailing length and direction of snowdrifts have been ascertained it may be possible to shorten the courses, but probably they will always have to be relatively long and many snow measurements will have to be made.

4. Surveys must be made on a sufficient number of courses properly located on each drainage basin to cover the variability of storms over the area.

WHEN SNOW SURVEYS ARE MADE

A snow survey should show the amount of snowfall accumulated during the preceding winter months. It is important, therefore, that surveys be made at the time of year marked by the termination of winter storms, because not until then can there be assurance that the snow mantle has reached a maximum for the year, nor can the final and most important forecasts of the year be made.

The general program in the Western States calls for a survey on about the first day of each month from January to May, inclusive, at a limited number of key courses, and surveys at all courses on March 1 and April 1. If a survey can be made on only one of these dates, April 1 is preferred. This schedule is thus ordered to make possible the regular water-supply forecast service required for efficient operation of irrigation projects, municipal water works, and hydroelectric plants. It is more than adequate to serve other purposes as well, except for the need of the northwest coastal section to know snow conditions throughout the winter so that its typically erratic winter floods may be guarded against. A schedule for this coastal section has not yet been adopted.

While the most important date in this schedule is the time of the year marked by the termination of winter storms, this date actually varies somewhat from place to place and from year to year. It may be March 1, April 1, or some intervening date. It has been impossible to fix a date that all snow surveyors will recognize as best for their sections as well as proper for a large area such as the Columbia River Basin.

Furthermore, the forecast service, like the surveys, must follow a rigorous time schedule. Actually, only timeliness is sacrificed by fixing April 1 as the date when the surveys are made on all courses and when the final and most important forecasts of the year are announced. If the courses are properly located, the snow lying on them the first of

April will still represent the winter's maximum snow mantle in water content, even though snow at lower elevations has melted to some extent and some run-off has already occurred. At least there may be assurance at this time that the winter storm period is practically over and that the measurement of the snow will be very near to the maximum for the year. Nevertheless, meteorological developments may prove that forecasts as of April 1 might have been made with equal accuracy 1, 2, or 3 weeks earlier, and since there is need for this information as early as it is obtainable, the March 1 surveys have considerable value. As a basis of tentative forecasts they should be as complete as possible for all courses.

Less effort to procure complete information is usually warranted in making snow surveys on January 1, February 1, and May 1. One key course on each important tributary of a major drainage basin should yield satisfactory data, but measurements are taken on more courses if the cost and effort required are small. They are useful as a means of following developments in water-supply conditions throughout the winter and early spring months. January 1 surveys are relatively the least important and may be omitted if a long trip is required and soft snow makes travel difficult. May 1 surveys are particularly useful because they indicate prospects for late-season run-off.

Though the first day of the month is specified as the date for making the surveys, some deviation from this date is permissible and frequently necessary; hence a period of 4 days before and 4 days after the first of the month (8 days) is prescribed as that within which the surveys should be made. If difficult travel into high country is required, it is expedient to take advantage of cold, fair weather for the trip. It is better that these data be procured several days before rather than after the first of the month to insure their prompt publication and use.

Locally there may at times appear to be little need for a survey, but always somewhere downstream are conditions that make maintenance of the time schedule necessary.

HOW FORECASTS ARE MADE

Water-supply forecasts based on snow surveys are made on the assumption that there is a simple relationship between the water content of the snow cover on a drainage area and the run-off from that area. Such forecasts can be made most simply and accurately if the major part of the precipitation occurs as snow at high altitudes, where there is little or no melting. For any drainage area for which dependable snow-survey data and run-off data are available for several consecutive years, a chart can be designed from which an estimate of the run-off, for a determined storage of water in snow, can be made. Such a curve will, of course, apply only to the drainage basin from which the data were secured and should be recalculated as the observations become available.

In table 1 are data for the Boise River Basin, in Idaho, where the attempt to locate the snow courses so as to obtain measurements representative of the drainage basin has been notably successful.

TABLE 1.—*Annual snow survey and run-off records from Boise River Basin, Idaho*

Year	Average depth of water in snow cover	Net run-off	Year	Average depth of water in snow cover	Net run-off	Year	Average depth of water in snow cover	Net run-off
	Inches	*1,000 acre-feet*		*Inches*	*1,000 acre-feet*		*Inches*	*1,000 acre-feet*
1930	24.1	1,117	1933	31.1	1,397	1936	40.2	1,831
1931	20.0	751	1934	21.4	874	1937	25.7	1,015
1932	34.6	1,783	1935	29.9	1,386	1938	45.9	2,312

The average depth of water in snow cover given in table 1 is the arithmetic mean of the means of the water-content measurements for the three courses on the Boise River Basin. The net run-off is the sum of the stored water accumulating in Deer Flat and Arrowrock Reservoirs during the period January 1 to April 1, the stream flow during the period April 1 to September 30 at Moore Creek near Arrowrock, and the stream flow (corrected for draft on Arrowrock Reservoir) at Dowling Ranch near Arrowrock.

These data are represented in figure 1 as dots. By the method of least squares a first degree function was fitted to these data. If R be defined as the net run-off in thousands of acre-feet and X as the average depth of water in snow cover in inches, the equation, represented by the straight line in figure 1, is

$$R=57.9X-369.4$$

Thus, the indication of the record through the last date shown is that the run-off of Boise River drainage basin increases, on the average, approximately 58,000 acre-feet per inch of increase in depth of water in the snow cover on the measured courses.

In forecasting, the curve is used as follows: If the average snow cover for the season has been found to contain 37 inches of water, the net run-off is estimated by projecting a line vertically from 37 until it intersects the curve, then projecting a line horizontally through this point until it intersects the vertical axis, which intersection occurs at 1,773. The run-off is therefore forecast as 1,773,000 acre-feet.

USES FOR WATER-SUPPLY FORECASTS

Irrigation

The desirability of making the maximum use of water in irrigation and the variation in the amount available from year to year call for water-supply forecasting. An accurate forecast guides farmers in planting their crops and permits efficient operation of irrigation works.

Flood Control

Snow-survey data may indicate the possibility of floods. Other factors, such as temperature variation from normal and occurrence of heavy rainfall, must be considered with snow-cover conditions in pre-

dicting when floods will take place and the heights to which the water will rise. The River and Flood Division of the Weather Bureau, the corps of Engineers, United States Army, and other governmental units similarly concerned with floods are promptly supplied with all snow-survey data. If the accumulated snow cover represents a potential flood hazard and reservoir capacity is available, immediate steps may be taken to prevent possible disaster by operating the reservoirs

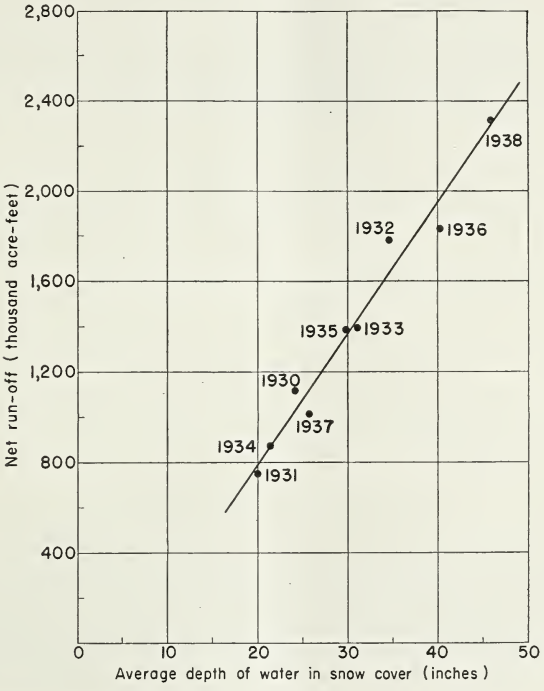

FIGURE 1.—Run-off forecasting curve for Boise River Basin, Idaho.

as flood-control works. Most of these reservoirs are used to store water for irrigation, power, and water-supply purposes, which require that they be filled during the spring run-off period. They can be used to good effect as flood-control works, if water-supply forecasts based on snow surveys reveal that the streams will carry more than enough water to fill the reservoirs after the major flood peak has passed.

WATER SUPPLIES FOR OPERATION OF HYDROELECTRIC PLANTS

Many power companies have long employed snow surveys to obtain indicators of stream flow on which to base operation schedules. The procedure is especially necessary where water is used for both irrigation and generation of electric power. For instance, at Boulder Dam the economy of generating as much firm power as possible on a

continuous basis and at the same time retaining enough water for irrigation makes it necessary to know in advance how much water the mountain snow cover will yield.

Watershed Protection

Much importance is attached to snow-cover data, particularly by the Forest Service, as an indicator of forest fire hazards and grazing conditions. Prolonged drought increases the danger of disastrous forest fires and diminishes feed for livestock and wildlife on the range. Any indications that forests will be dry afford an opportunity to put into effect measures that aid in preventing and controlling fire and in avoiding the overstocking of the range.

Stock Water

Water is so scarce at times on some range lands that the flow of springs is the factor limiting the use that may be made of the feed. Correlation of the past performance of springs with snow-cover data afford a proper basis for granting grazing privileges.

Municipal Water Supply

Cities such as Los Angeles and Denver, which depend on storage, stream flow, or springs for water, are benefited by and rely confidently on forecasts based on snow surveys.

Estimates of Snow Load

The ease with which snow densities may be ascertained with standard snow-sampling equipment has prompted its use for determining the snow load that structures must be designed to withstand, and density measurements are being made with snow-sampling equipment in order that power necessary to open snow-bound roads may be gaged accurately.

Farm-Loan Servicing

The Federal land banks and similar credit agencies study the forecasts in order to restrain or encourage farm operations that may affect the ability of farmers to meet their financial obligations.

Crop Estimates

The Federal crop reporting service and other agencies concerned with statistics relating to crop production use snow-survey measurements as indicators of the types of crops that will be planted on irrigated land and of prospective harvests. Promise of an ample supply of late water leads to the planting of late-maturing crops, whereas only early maturing crops will be grown if it is known that the water supply will be short, especially during the late growing season. Moreover, the amount of water to be available is the major factor limiting crop yields. Thus water-supply forecasting is helpful in predicting not only unit yields but also the acreages of various crops.

Mining Operations

The water supply is frequently the chief concern in planning the operations of mines, especially placers, and in smelter operation; data obtained in the snow surveys are accordingly of considerable use to the mining industry.

Care and Protection of Wildlife

The Migratory Waterfowl Division of the Bureau of Biological Survey maintains numerous inundated areas throughout the West as feeding grounds and refuges for wildlife. Elaborate systems of dikes and diversions have been required for regulating the depths of water and for extending or restricting most of the flooded areas in accordance with amounts of water available. Water-supply forecasts based on snow surveys are useful in effecting the best operation of these systems.

Industry and Commerce

The water-supply outlook is of general interest throughout the West because persons interested in production, trade, shipping, banking, and employment all follow the water-supply trend somewhat closely.

SNOW-SAMPLING EQUIPMENT

The Federal equipment (fig. 2) furnished by the Government for sampling is essentially the same as the Mount Rose and the Utah equipment. Each consists of a snow sampler, which is a 1¾-inch (outside diameter) slotted metal tube with a snow cutter securely fixed in its lower end and with a scale in inches stamped on its exterior surface throughout its length; a spring balance for determining the weight of snow cores; a wire cradle for supporting the tube while it is being weighed; and tools for operating the snow sampler. Since the tube, cutter, and balance are different in the three sets the characteristics of each set should be known.

Federal Equipment

Federal snow-sampling equipment (fig. 2) is the name used in this publication to specify the set supplied by the Federal Government. Federal Mount Rose snow sampler (fig. 2, *A*) is the name of the snow sampler in the Federal equipment. It is a duraluminum tube in 2½-foot sections, into the lower end of the first section of which is shrunk-fit a 1.485-inch (inside diameter) case-hardened, cold-rolled steel snow cutter (fig. 2, *F*). The tube sections are assembled in lengths up to 20 feet with threaded couplings of duraluminum (fig. 2, *G*).

The Federal balance, shown in figure 2, *B* (capacity: 12.5-foot tubing; or capacity: 20-foot tubing), is made of duraluminum, is tubular in shape, and short for convenience in carrying and handling. The length restriction requires that these balances be made in two sizes and that their spring be placed under tension. One balance,

stamped "Capacity: 12.5-foot tubing," weighs snow cores up to 12½ feet long and suffices for most snow surveying. Its spring is under tension equal to or slightly less than the weight of the first and second

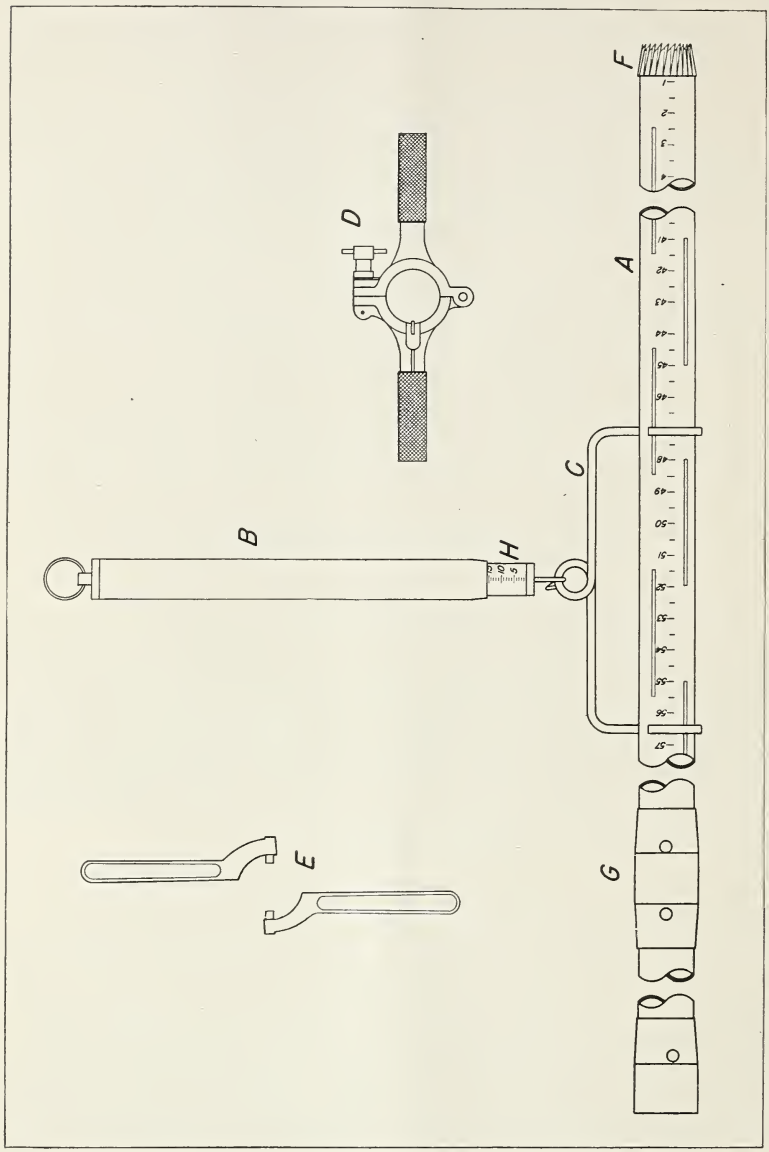

FIGURE 2.—Federal snow-sampling equipment: *A*, snow-sampling tube; *B*, tubular spring balance (12½-foot tube capacity); *C*, cradle; *D*, driving wrench; *E*, spanner wrenches; *F*, cutter; *G*, screw couplings; *H*, scale (in ounces).

tube sections, which requires that the Federal Mount Rose snow sampler used with it be at least 5 feet long; otherwise, the weight of the empty tube cannot be determined. The other Federal balance, stamped "Capacity: 20-foot tubing," is for measuring exceptional depths of snow. Its spring is under tension equal to or slightly less than

the weight of a 12½-foot Federal Mount Rose snow sampler and thus requires that the snow sampler be at least of that length. These two balances are graduated to weigh in ounces, and, since the snow cutter of the Federal Mount Rose sampler cuts a snow core 1.485 inches in diameter, the scale reading is equivalent to inches depth of water in the sampled snow cover. In an emergency this feature permits the use of any commercial balance accurate to 0.5 ounce. The scale of ounces or inches on Federal balances now in use varies. Each division on the present low-capacity balance represents 1 ounce or 1 inch, whereas the division on the present large-capacity Federal balance represents 2 ounces or 2 inches.

To weigh a snow core with these balances it is necessary to get a weight for the empty sampler (not its true weight) and to subtract it from the combined weight of core and sampler, which is obtained by weighing the core while it is inside the sampler.

Mount Rose Equipment

The Mount Rose snow-sampling equipment is the apparatus for measuring snow developed by J. E. Church while he was initiating water-supply forecasting based on snow surveying in Nevada.

The Mount Rose snow sampler differs from the Federal Mount Rose snow sampler in that it is steel throughout, is either in one piece or in 5-foot sections, and has a snow cutter with an inside diameter of 1.5 inches.

The Mount Rose balance is the dial type, especially calibrated so that weight of snow core is indicated as inches depth of water; and it provides for a zero setting of the indicator on the scale of weights so that the weight of the empty sampler may be eliminated in determining the net weight of snow cores. To weigh a snow core with this balance the weight indicator is set at zero while the empty sampler is on the balance. This adjustment is made by turning the knurled nut near the top of the face of the instrument. Tare thus having been determined, the net weight of the snow core is the weight procured when the sampler, with enclosed snow core, is placed on the balance.

Utah Equipment

The Utah snow-sampling equipment is a modification of the Mount Rose equipment, developed in Utah by George D. Clyde. It served largely as the model for the Federal equipment, with which it is identical except that it is lighter.

Tools

A pair of spanner wrenches (fig. 2, *E*) and a driving wrench (fig. 2, *D*) are furnished with the Federal equipment. The Mount Rose set includes these tools and a metal blade for loosening snow that sometimes sticks inside the sampler.

The spanner wrenches are steel and are intended for uncoupling the sampler. Holes into which they fit are required in both ends of each coupling.

The driving wrench is a pair of handles for operating the sampler and is made principally of cast aluminum. To secure it to the sampler, it is opened and the key is inserted into one of the slots in the sampler tube; it is then closed and fastened.

CARE OF EQUIPMENT

Snow-sampling equipment is designed to withstand rough treatment. Nevertheless, in some respects it is delicate and should have the best care possible because if it is damaged while in use the accuracy of the measurements may be impaired. Moreover, the equipment is expensive. In the last large order placed by the Government for its Federal snow-sampling equipment the price of each of the parts was as follows:

First or bottom sampler section (including cutter attached)	$8.86
Each additional sampler section	7.10
Balance	9.17
Driving wrench	11.60
2 spanner wrenches at $0.28½	.57
Aluminum notebook holder	.65
Canvas carrying case	1.25

The total cost of the 5-foot sampler was $39.20 and of the 12½-foot sampler, $60.50. When purchased in small quantities, the cost of these parts or the equipment as a whole is approximately double.

Keeping Tube Free of Dents

Dents can be removed by using a short cylindrical plug of steel a little smaller than the inside of the sampling tube. This swage, if provided with a rounded top, can be shoved through the damaged section of tube, thus forcing the dents back. Gentle hammering on the exterior of the tube with the swage in close contact inside will give a smooth, finished job.

Repairing and Replacing the Cutter

The cutter should be kept sharp and true for cutting easily and accurately through hard snow crusts and ice layers that may be encountered in the snow pack. If not broken or too dull, the points of the cutter teeth may be sharpened with a fine half-round file. The filing should be done on the sloping sides of the teeth. After the teeth have been filed until sharp, care should be taken to remove any burred or feather edges. If the cutter is so damaged that it may not be sharpened with a file, the sampler or cutter end should be returned to headquarters for repairs or replacement. Removal of rock from the spots where snow cores are procured will usually insure long life of the cutter and reduce to a minimum the amount of sharpening and straightening of points.

Keeping Threaded Duraluminum Couplings From Seizing

When threaded couplings of duraluminum fit too snugly, the threads seize or weld together. If such joints do not screw together loosely, they may be made to do so by placing a small amount of fine

valve-grinding compound and oil on the threads and working the joints for a time. After this operation, the threads should be thoroughly cleansed with kerosene or alcohol. If a joint is allowed to seize, application of a mixture of oil and kerosene will usually facilitate uncoupling. Supplied with each Federal Mount Rose sampler is a tin of antiseize grease consisting of petrolatum and zinc dust. This preparation, properly applied, will prevent the seizing if there is enough play in the joints to let it stay on the threads.

Using Spanner Wrenches for Uncoupling Tubes

If much ice is encountered during the sampling operation, the tube joints become set so tightly that they cannot be taken apart by hand without the aid of wrenches. This trouble is not due to seizing, and it occurs with both duraluminum and steel tubes. Spanner wrenches only should be used for loosening duraluminum couplings, since other tools damage samplers made of this relatively soft material.

Avoiding the Bending of Tubes

Before starting to take the sample, the operator should make sure that he is standing in a stable position from which he may work without clinging to the tube for support, since the tube may be easily bent if it is so used on a sidehill, especially after a portion has been sunk into the snow. A long tube is more easily bent than a short one; therefore, it is desirable to keep the sampler as short as the length of tube sections and snow depth will permit while working on a sidehill. When it is necessary to stand on the handles of the driving wrench, care should be taken that the wrench is not more than 2 feet above the snow, and one operator should help the other to gain his standing position on the wrench.

Keeping Sampler Coated With Paraffin or Shellac

If there is a variation between the temperature of the sampler and the snow cover or between the temperature at the different depths within the snow cover itself, snow will stick to the bare steel or duraluminum tube so tightly that accurate sampling becomes very difficult, if not impossible. Coating the tubes with paraffin or shellac largely overcomes this trouble. Snow surveyors hold different opinions as to which is the better. The experience of some indicates that shellac is better for the steel tubes and paraffin for duraluminum, whereas other surveyors prefer paraffin for both steel and duraluminum. Paraffin lasts through only one season; shellac will last longer if two or three coats are applied.

Perhaps the easiest way to apply the paraffin under field conditions is as follows: Clean the inside of the tube with a tight-fitting flue brush or a wad of steel wool on the end of a wooden rod. Melt the paraffin in a pan, being careful not to burn it. A good arrangement is to set a cup of paraffin in a large pan of water and heat the water. Heat the tube with a blow torch by placing the tube on a bench, slotted side down, and inserting the flame in one end—2 or 3 seconds is sufficient for the 2½-foot length. Stand the tube on end, male

threads down, and after wiping threads with petrolatum apply the melted wax to the inside with the swab.

The shellac coating is easily applied in the field as follows: Clean the tube in the same manner as for the paraffin coating. Put a layer of shellac on the outside of the tube with a brush and allow it to dry thoroughly. Cover the slots with adhesive tape, coat the threads with petrolatum, push the swab into the tube until it is within 3 inches of the free end; hold the tube upright with the free end uppermost, fill the free end with shellac, and gradually work the swab to the lower end with short up-and-down strokes, which will effectively rub the shellac uniformly over the inside. These operations (except cleaning) should be repeated two or three times after allowing the previous coating to dry thoroughly.

After the coating job is complete, the paraffin or shellac is easily wiped off the threads, to which petrolatum has been applied. The tube sections should then be assembled in their proper order to insure that the threads work well.

Keeping Balance Accurate

The balances should frequently be tested for accuracy. They should weigh accurately to one-half division; if they do not, they should be returned for replacement. They should be well protected while being transported and while in storage, carefully handled while in use, and wiped clean and dry after each use.

Cleaning and Drying Equipment After Use

Before packing or putting away the snow-sampling equipment, especially the sampler and balance, all parts should be thoroughly cleaned and dried with a cloth to put them in good working condition for the next survey.

Carrying Equipment in Case or With Harness

Canvas cases are provided with individual pockets for holding each part of the Federal equipment (fig. 3). These cases are intended primarily to protect the equipment against wear and accumulation of grit during conveyance on truck or sled and to prevent misplacement or loss of the various parts. If the outfit must be taken on extended ski or snowshoe trips these canvas cases also serve fairly well as a safe place to carry the 30-inch tubes. Two straps may be attached for carrying the case like a knapsack without a pack board, or it may be lashed securely to a pack board if one is carried.

If the tube sections are long, as they are in some of the Utah and Mount Rose equipment, it is safest to carry them fastened under the left arm by a strap over the right shoulder and another around the chest. This leaves both arms free. There is much chance of damaging the equipment and the carrier through accident during travel; hence, it is important that the arrangements for carrying the tubes shall be as convenient as possible.

FIGURE 3.—Removing snow-sampling apparatus from canvas carrying case preparatory to use.

SNOW-SAMPLING PROCEDURE

ACQUAINTANCE WITH LOCATION OF SNOW COURSE

At least one member of a snow-survey party should have knowledge of the course, gained either by having helped to establish it or by having participated in a previous snow survey. If it be known that an entirely new crew will be called upon to handle the surveys, at least one member of the new crew should have had opportunity to view the course at some time during the preceding summer or fall.

LOCATING THE SPECIFIED SAMPLING POINTS

Every snow-survey crew should carry a sketch map showing the lay-out of each snow course they are to measure. A snow survey should start from the end designated on the sketch as the beginning of the course, and the samples should be measured, recorded, and numbered in exactly the order shown. The distance from the initial snow-course marker to the point where the snow is first sampled and the distances between samples from that place to the end of the course should be as nearly as possible the same as those shown on the sketch. In laying out a course and in maintaining it, the ground surface is cleared of rock, fallen trees, stumps, and brush. This clearing is done 3 to 5 feet in all directions from each point selected for sampling,

and watercourses and irregular ground surfaces are avoided by at least that distance. The characteristics of ground and snow surfaces along a course also limit the size of the spots within which the snow should be sampled. Missing one of these points by more than a few feet may result in serious errors in the snow survey. It is best to use a metallic tapeline to measure the distances, but a stout cord of appropriate length, knotted or tagged to suit the needs of a specific course may be used instead. Stakes high enough to extend above the deepest snow and offset from the course far enough not to affect the snow cover may be placed as markers opposite each point where snow samples are to be taken, or at as many points as necessary to minimize possible error in the adopted method of measuring. If a course meanders through timber and if small openings are used as places of sampling, two or three marked trees around each point will locate them. The less sure means of following a course by pacing while on skis or snowshoes is not good general practice, but is allowable if the ground surface is uniform and well-cleared and the distances between objects of known position along the course are short.

On a key course that is measured several times during the winter, it sometimes occurs that the dirt from the cutter thrown on the snow during an early measurement melts the snow, producing a pot hole or cupped depression in the snow at the sampling point. This is purely a local accident. To avoid error and show the correct amount of snow at the course, the later samples should be taken far enough away from the point actually called for to be beyond the zone of melting caused by the dirt. When it is expedient that a sample be taken more than 3 feet from the intended point, the distance and direction of departure should be recorded under "Remarks" on the field-note form.

Assembling the Sampler

The sampler should be made up in sufficient length to reach the ground surface with a minimum number of tube sections. When the sections are assembled, care should be taken that the numbering on the outside of the tube is consecutive from zero to the maximum length of tube used. This will prevent incorrect readings of snow depth, which might be made if a section were out of its proper place in the assembled tube. It is important that the first section, which holds the cutter, be used and that the cutter be in place and true to its intended inside diameter, for besides facilitating penetration of the snow cover the cutter controls the diameter of the snow core. If this diameter is other than that intended, the most significant determination made during a snow survey, the water content of snow, will be in error. Time may be saved in assembling the 30-inch sections of a Federal Mount Rose snow sampler if the compartments of the canvas case are labeled to correspond with the tube lengths carried: 0–30 inches, 30–60 inches, and so on.

Cutting a True Core of the Snow Cover

The sampler should be empty; raise it vertically over the head and sight through the tube to see that it is.

To cut the core, the sampler, cutter end first, is forced vertically downward through the snow cover (on slopes as well as on level surfaces) until it reaches the ground. If snow conditions permit, a steady downward thrust intended to effect the uninterrupted flow of the core into the tube is best. A minimum amount of turning in a right-hand direction is possible without interrupting the downward thrust; this brings the cutter into play, which is desirable for quick penetration of thin ice layers. Stopping the downward movement tends to clog the cutter. Plunging is objectionable because it packs the snow already in the sampler and thus increases the resistance to the entrance of more. If the snow pack is deep and dense or otherwise difficult to sample, slower and more or less interrupted progress in putting the sampler down is unavoidable. More turning may be required, and a driving wrench may be needed in order that the necessary force or weight may be applied. It is sometimes necessary to stand on the driving wrench to get more weight on the sampler. A thrust of the body from the knees up, with the feet kept firmly on the handle of the wrench will often force the sampler through an obstinate snow crust or ice layer, but the surveyor should never jump up and down to force the sampler through the snow pack.

Weighing the Empty Sampler

It is necessary to account for the weight of the empty sampler and the cradle to ascertain the weight of the snow core. This should be done before the first sample is taken and frequently thereafter, since enough moisture and snow particles may adhere to the sampler while a course is being measured to affect its weight materially.

In this and the later weighing operation the balance should be held only by the ring provided for that purpose and allowed to hang vertically. The Federal and Utah balances, especially, should not be held with the hand gripped around the cylinder, since this is likely to cause binding between the inside and outside cylinders and may result in faulty weight.

It is best to hang the balance from a pole or by means of a loop over the operator's neck. It is unsteady if held in the hand, and the scale is therefore hard to read. A special pole for this use is sometimes provided if the snow course is easily accessible. If the course is distant, however, this pole is rarely taken along, the snow surveyors preferring to pick up a suitable pole at the site; or, failing this, they may suspend the balance from the tip end of a ski or snowshoe, or from ski poles. A 5-foot ski pole is very satisfactory for this purpose; the hand strap may be run through the ring on the balance and over the top of the pole to make a good fastening. The surveyor weighing the samples may steady the pole with one hand. A good support may also be improvised with two ski poles in the following manner: Thread the hand loop of one pole through the loop of the second pole and cast it over both poles. String the loop of the second pole through the ring on top of the balance and cast the loop over both poles. Spread the poles, making a sort of A frame, and allow the top to lean toward the operator, so that the balance will swing clear.

It occasionally happens that snow will adhere to the tube and stop the flow of the core in spite of the shellac or paraffin coating. This is reported to occur when the sample is down 18 inches or so. The upper few inches of core is partly melted from contact with the warm atmosphere or warm sampler, and as the sampler is carried into the cold depths of the snow pack it becomes colder and the snow core may freeze or stick to the tube. This occurs when the temperature of the sampler is warm (owing to much handling or exposure to sun) in comparison with the temperature of the snow, and vice versa, or when the temperature of the surface layer of snow is above freezing and that of the underlying layer is below freezing, and vice versa. If this action is so rapid that it cannot be overcome by quick driving of the sampler, it may be avoided by delaying the survey until temperature conditions become equalized. It is sometimes overcome by cooling the tube, which can be done by laying it in the snow or keeping it in the shade for a while.

During the spring of 1938 great depths of snow laid down in the January-February storm period, without any intervening time for consolidation or packing as the snow accumulated, formed a layer of a flocculent noncrystalline snow deep in the snow mantle. This snow, which the snow surveyors termed "corky snow," had a tendency to choke the throat of the cutter. When the throat is choked, snow will not enter the tube no matter how much the sampler is weighted and rotated, and any downward progress amounts to pushing the snow aside as though a solid stock were used. This is true regardless of how the cutter becomes choked or clogged. For this particular type of snow, choking of the cutter can be prevented by allowing the sampler to penetrate the snow gradually under its own weight (with very little or no pressure by the operator), the tube being slowly rotated, first a short distance in one direction and then in the other. Sometimes it requires about 10 minutes to get the sampler down in this manner, but it appears to be the only way under such conditions to get a true sample in one core length. This method has been called tickling the tube through.

If the tube cannot be driven either by rotating, forcing, standing on the driving wrench, or tickling, a sample must be procured in two pieces. The first piece will be from the surface down to the hard layer that chokes the cutter or stops the sampling altogether. When this layer is reached and before the sampler is withdrawn, the hole is enlarged by rotating the top of the tube in a circle, which makes the hole cone-shaped. While the tube is rotated, care should be taken to keep the back of it against the side of the hole so that foreign snow will not have a chance to enter the tube through the slots. The sampler is then carefully withdrawn, and the weight and length of this piece of the core are set down on the back of the field-note form. The partial core is then dumped and the sampler gently lowered into the enlarged hole, care being taken to center it exactly to prevent knocking snow from the sides. With the sampler empty it is usually possible to continue through the hard layer and downward to the ground without further clogging the cutter. The snow-depth reading is made and recorded in the usual manner. The length and weight of this second part of the core is likewise put on the back of the field-note form. Total core length and total water

content are computed thereupon so as to show clearly how they were arrived at. By taking the sample in two cores in this way it is often possible to get a sample that otherwise could not have been obtained. Under extreme conditions it has been necessary to take the core in three sections. This method is not advocated when a single core can be procured, since it may give a measurement of water content greater than the actual amount.

The experienced operator can usually tell when the tube has penetrated the snow cover and has come in contact with the ground. A layer of ice or a hard layer of heavy snow will, after one or two rotations of the cutter, give back a slick, hard, greasy feeling. Grass roots, gravel, or rock will give a somewhat rough feeling. Mud will give a gummy feeling.

Measuring the Snow Depth

With the cutter at or slightly below ground level and the sampler standing vertically, the reading on the inch scale that corresponds to the top of the snow is observed. When the depth the sampler has penetrated beyond the bottom of the snow cover is ascertained and deducted from this reading, the result is recorded. This is an important reading, since it is used in checking and computing the water-content measurement (weight of snow core) of individual samples that are questioned or missing.

Retaining the Core While Withdrawing the Sampler

To prevent loss of core through the cutter end while the sampler is withdrawn from the snow, sufficient soil is gathered in the cutter to serve as a plug. To what extent this will have to be done depends on the condition of the snow. An inch of solid soil may be required to hold slush. A trace of ground litter on the lower end of the sampler indicates that no loss has occurred. Snow surveyors do not wish to pick up more soil than necessary, since all must be carefully removed before they weigh the core to get the water content. Usually the shoulder on the inside of the cutter will hold the core in place.

Measuring the Length of Core

The length of snow core obtained is observed through the tube slots and read on the inch scale on the outside of the sampler. After this reading is corrected for any foreign matter picked up in the cutter end, it is recorded. The sole purpose of this reading is to provide a means for quickly judging whether a complete sample of the snow cover has been procured. The length of a true core is not 90 percent or any other fixed part of the snow depth for all conditions of snow, but the relation of snow-core length to snow depth will hold fairly constant on an individual course at a particular time.

Weighing the Core

The weight of the snow core discloses the water content of the snow cover at the point of sampling. The weighing apparatus shows this

in inches of water. To determine the water content accurately for the snow course as a whole is the aim of the survey. Before placing the sampler containing the core on the balance, the surveyor should carefully remove any foreign matter that may have been picked up by the cutter from the ground. If either the Federal or the Utah balance and its sampler is used, the weight procured at this time is that of the snow core plus tare. It is read and recorded as such. If the Mount Rose balance and sampler are used, the reading is the water content in inches (the tare having been taken into account by setting the scale indicator at zero during the weighing of the empty tube), and it is so recorded.

When sampling in a stiff breeze, the surveyor will find it less difficult to hold the sampler steady while weighing if the cutting point is directed into the wind.

Dumping the Core

The core is dumped by allowing it to slide backward from the cutter through the tube, but usually the sampler must be tapped against a solid object on the ground. It will be found convenient for this purpose to tack a heavy piece of rubber belting (about 2½ by 3 inches) or rubber similar to that used for ski footplates to the top of one or both skis just ahead of the toeplate.

Sources of Error and Their Elimination

Errors may occur in snow surveying as in any other work in which measurements are used. Careful attention to the work in hand will eliminate most of the errors due to faulty reading and recording of snow depth, core length, and weight of water content, but there are two sources of error often overlooked by even the most conscientious observers. Even though the sampler has been all the way through the snow and no loss of core has occurred during its withdrawal, the weight of the core may not be a true indication of the water content of the snow cover. This may be due to either an incomplete core or ponded water under the snow cover.

INCOMPLETE CORE

An incomplete core may result from the clogging of the cutter by corky snow or layers of ice; from sticking of the snow caused by unequalized temperature conditions; or from an obstruction in the snow such as a pine cone, a stick, or a loose nodule of ice (frozen tree drippings), which is pushed ahead of the sampler. The difference between lengths of core and snow depths, wide deviation from the weights of water content recorded for previous samples, and other characteristics of the snow cover observed while sampling indicate to a competent snow surveyor that a core may be incomplete. The remedy lies in taking additional samples a foot or so apart, using all known methods for overcoming conditions that might account for a faulty core. If, in the end, a longer core cannot be procured, the measurements should be recorded together with a statement setting forth how conditions at the point vary from those where satisfactory samples have been procured. Condition of snow may

vary from hillside to draw, in and out of timber, and with differences in exposure. After all, a core that is questioned may be a good one. Owing to the fact that the snow is soft or to some other condition of the snow at the particular point where the core is taken, it may have slumped or settled in the tube. When the notes are worked up it may be possible to use such erratic data if they are properly explained; otherwise, it may be necessary to discard them, though to do so impairs the value of the survey.

PONDED FOREIGN WATER

Ponded water may generally be attributed to poor drainage of the area on which the snow course is laid out. Water runs out of the melting snow pack from the slopes surrounding the snow course and ponds up temporarily under the snow on the flatter slopes of the snow-course site. The amount of this ponded water will depend on the lay of the land and the amount of melting on the slopes before the time of the snow measurement and not at all on the character and amount of the snowfall. For this reason any gathering of water beneath the snow at the snow course, if a like accumulation is not also observed on the slopes of the watershed beyond the limits of the snow course, upsets the relation between the measurement of the snow pack on the course and the depth of snow cover on the surrounding country, of which the snow course is supposed to be representative. Therefore when the operator finds water running from the end of the tube after withdrawing a sample, he should not bother to weigh the core at all, since the weight would include a large amount of foreign water and would not represent the general area. The depth of the snow alone should be recorded, and dashes placed in the spaces reserved for length of core and weight of core. The words "ponded water" should be entered under Remarks. The average density of snow for the snow course can be determined from the samples without ponded water, and the density so derived can be applied to the average depth of snow at the course, which average will take into account the depth at all the sampling points, including those at which water was found. This is the method of calculation used in other cases of missing or faulty weight measurements.

If the ponding of water appears to be a regular occurrence under the snow of any course it is necessary to relocate that course.

Procedure Under Special Conditions

Under trying circumstances and where many samples are to be taken, there may not be enough time to take them at all points. Samples should then be taken and weighed only at every second or third point, and at all intermediate points only the depth of snow should be measured. Usually this procedure is unnecessary and should be resorted to only when sampling conditions are extremely difficult or the approach of darkness makes unlikely the completion of the survey called for on the sketch.

Occasionally the depth of snow exceeds the length of the sampler. This occurs because the depth of snow to be sampled has been misjudged. The correct remedy with respect to future measurements is

to provide a longer sampler, but the immediate problem may be solved by the following expedient: With the sampler already down its full length, place a handkerchief or similar article loosely into the top of the tube, keep snow away from the tube to a depth of a foot or so, and stand on the sampler to force it down farther. At frequent intervals remove the wadding from the tube and observe the distance to the top of the core. When the core reaches the top, the limit to which this method may be safely used has been reached. If the sampler can thus be thrust the full depth of the snow cover, the measurements can be made and recorded as usual, except that the distance from the surface of the snow to the top of the sampler must be added to its length to determine the actual depth of snow. If the core is longer than the sampler, the sample should be taken in two pieces, the first with the sampler down its full length and the second with sampler forced farther, as previously described. Other procedures prescribed for taking the core in two pieces when ice or snow clogs the cutter may also be followed.

Recording the Notes

Small forms on white, waterproof paper securely bound in pads and perforated to facilitate removal are issued for field use. This pad consists of 25 forms, 2 green cover sheets upon which are printed brief instructions, and a durable pasteboard back. It is serviceable without additional covering, but usually is carried in an aluminum spring-back notebook holder. A small print of the snow-course sketch-map shellacked to the inside of the metal holder and a pencil secured to the holder by a stout cord make a convenient arrangement for recording survey data in the field. It is required that original field notes be on these sheets, and undoubtedly they serve most conveniently and are best for the purpose. Carbon copies of original notes, though desirable, are not provided for because they are not always legible.

A sharp 4H pencil should be used in writing the notes.

The name of snow course, the date, and other information should be entered in the spaces at the top of the data sheets. In addition, the length of sampler and balance number should be inserted as shown in the sample set of notes. (See fig. 4.)

The sample number entered in the notes should identify the measurements that follow it with the point on the sketch map that bears the same number. To avoid error, the survey of a course and the order in which the notes are recorded should start at the No. 1 sampling point and be carried through consecutively according to the numbering on the sketch. Care should be taken that the numbering of the samples be not the reverse of that shown on the sketch.

The net lengths of cores and the net depths of snow should be entered in the notes to the closest inch.

Weights should be entered to the closest one-half inch. Half inches should be recorded as fractions instead of decimals, so that misinterpretation will be impossible.

The back of the form as well as the Remarks column may be used for noting significant information and calculations such as are

required when a sample is taken in two or three pieces. In addition to explanations and observations having to do with the measurements the following should be commented upon:

Condition of soil under snow (that is, dry, wet, frozen, etc.).
Condition of snow cover.
Distribution of snow cover (presence or absence of much drifting and relative amount of snow at high and low elevations in comparison with that in past years).
Status of stream flow (low, normal, or high for time of year).
Weather (storming, fair, cold, or warm).

FIELD-OFFICE PROCEDURE

Computing Field Notes

If the field notes on a snow survey are mailed or delivered, they need show only basic data and other information recorded in the field when the survey was made. If the results are telegraphed or otherwise transmitted in brief form, the average snow depth and average water content for a course must be computed in the manner shown on the sheet of sample notes (fig. 4).

If Federal or Utah snow-sampling equipment has been used, Water content—Inches (column 7) is determined by subtracting Weight of empty tube (column 5) from Weight of tube and core (column 6).

FEDERAL AND STATE
COOPERATIVE SNOW SURVEYS
90" Tube — Balance No. 324

State Wyoming
Drainage Basin Columbia - Snake
Snow Course Skyline
Party John Doe & Richard Roe
Date March 30, 1938

*Description or Number of Course	**Sample Number	Depth of Snow Inches	Length of Core Inches	Weight of Empty Tube	Weight of Tube and Core	Water Content Inches	Density Per Cent	Remarks
A-N45° E.	1	74	68	18	45	27		3N. of Sta.
	2	71	67	"	44	26		
	3	70	65	18½	44½	26		(1)
	4	73	67	"	43½	25		
	5	74	68	"	45	26½		
	6	70	65	18	43	25		
B-N45° W.	7	60	50	"	40	22		(2)
	8	70	66	"	45	27		
	9	68	65	18½	41½	23		
	10	67	63	"	42	23½		
	11	68	64	"	43	24½		
	12	70	65	18½	43½	25		
	13	68	64	18½	43	24½		
	14	70	62	"	40½	22		
Totals	14	973				347		
Av.		69.5				24.79		

*Show number or description as given on sketch map, i.e., "Course No. 1," or "Major Course," or "N 5° E," etc.

**Always start measurements for sampling from the *initial* point as shown by the sketch map of the course and follow the spacing for samples as indicated. Particular care should be taken to note any *irregular* spacing between samples.

No. 1 of 1 sheets. Comp. by J. Doe Checked by

46330 9-37 12500 G.P.O.

(1) Core taken in two pieces
1st Section
40" depth
38" Core
32½" Wt. core & tube
2nd Section
30" depth
27" Core
30½" Wt. tube & Core
40 + 30 = 70" depth
38 + 27 = 65" Core
(32½ + 30½) - (18½ + 18½) = 26" = Water Content.

(2) South exposure & no shade - Snow noticeably heavy. Result checked by two measurements.

Snow generally crusted and well packed - less than usual amount of drifting.
Soil generally moist and unfrozen beneath the snow.
Snow generally gone on South slopes below elev. 4500'
Stream flow about normal
Weather clear — temperature at snow course about 32° F.

FIGURE 4.—Sample snow-survey field notes. Entries in columns 5 and 6 are not necessary when Mount Rose equipment and dial scales are used.

Sample Field Notes

Course averages for Depth of snow—Inches (column 3) and Water content—Inches (column 7) are computed by adding these two columns separately and dividing each summation by the total number of sampling points (last number in column 2). The divisor should be the same even though there is no snow at some of the sampling points. The division is carried out two places beyond the decimal point, but is reported to only the first decimal. The first decimal figure remains the same or is increased by 1 in accordance with the following rule:

If the last significant figure is less than 5, the preceding figure remains the same; if greater than 5, the preceding figure is always increased by 1. If it is exactly 5, the preceding figure remains the same if it is an even number but is increased by 1 if it is an odd number.

Examples:

Original:	Rounded:
18.54	18.5
18.56	18.6
18.45	18.4
18.55	18.6

If the average water content for the course must be available for telegraphic transmission and if it has been impossible to get water-content weights for one or several of the sampling points or if ponded foreign water has made it inadvisable to procure them, a missing water content is calculated as follows:

(1) Add the snow depths for all sampling points where it has been possible to get a satisfactory water-content weight.
(2) Add the satisfactory water-content weight.
(3) Divide (2) by (1) to get an average density of the snow cover in percent.
(4) Multiply snow depth of point for which the weight of water content is missing by (3) to get calculated water content, thus:

$$(1)=973,\ (2)=347,\ \frac{(2)}{(1)}=\frac{347}{973}=0.3566=35.66 \text{ percent.}$$

For example, assume sample No. 10 of the sample notes (fig. 4) has no water-content weight: 35.66 percent of 67 inches=23.9 inches, the calculated water content, whereas 23.5 inches was the measured water content.

Transcribing Field Notes

Though regional snow-survey offices take care of most demands for copies of snow-survey notes, there is occasional need for doing some of this work in the field offices of cooperating agencies. A duplicate of the form used for recording the notes made in the field is provided for making the copies. The form is printed on letter-size inexpensive pink paper ruled to conform with the double spacing of typewritten copy. It is packed in pads of 50, insecurely held together by glue along one edge so that an individual sheet or several may be removed without damaging the paper. The color signifies that the data have been copied. The ruling provides ample space for copying on typewriter or with pencil or pen.

All copies should be checked against the original copy or source from which the data are copied or received. The source should be stated on each copy; for example: "Copy of original field notes;" "Copy of telephoned report."

Reporting by Telegraph

Telegraphic reports are usually sent by snow surveyors only to regional or State directors of snow surveys, who use them for making preliminary calculations and while awaiting receipt of the original data sheets. Once ordered, the practice should be continued until other instructions are issued. Telegrams are sent at cheapest Government rate, collect. They should state, in words and figures that will cost the least, the name of course, date of survey, average snow depth (column 3) and average water content (column 7). The following form is prescribed: SKYLINE MARCH 30 SNOW 69.5 WATER 24.8.

Verification of telegraphic reports sent to regional offices should be forwarded as soon as possible. This may be the original field notes or, if these are not available, the material from which the telegram was prepared.

Reporting by Radio and Telephone

Short-wave radio service is being used only to a limited extent for the transmission of information from the field to regional or cooperating offices. Telephone service is used more extensively. In transmitting notes by radio, the dates and hours of contact are usually arranged in advance. In transmittal by radio or telephone it is recommended practice to read the separate columns one at a time from top to bottom, securing a check on each column before proceeding to the next. Radioed notes should be checked back from the receiver to the transmitter for approval of reception accuracy.

Forwarding Original Field Notes

Original data sheets are the best records. It is necessary that they be sent to the authority who must assume final responsibility for accurately reporting results, since otherwise proper verification of the records and checking of the calculations may not be claimed. The proper depository for these original records is the office of the Division of Irrigation, Soil Conservation Service, or an affiliate that directs snow surveys in the State or drainage basin from which the data originate.

Retaining Copy of Notes at Station of Chief Snow Surveyor

Each leader of a snow-survey party is requested to copy his field notes carefully on one of the pink forms and to check it against the original before it leaves his hands. This precaution may prove important if an original data sheet should go astray in transit. Furthermore, if these copies are preserved and referred to from year to year they help the men who regularly make the surveys to perfect their skill and serve to familiarize new men with their duties.

Reporting When There Is No Snow

The prescribed reporting procedure should be followed even though there is no snow on a course. That fact alone is often important. The report should state also the condition of soil (dry or moist), and the status of stream flow (normal or otherwise) should be commented on even more particularly than usual.

IMPROVEMENT AND MAINTENANCE OF SNOW COURSES AND FACILITIES FOR SNOW SURVEYS

While it is not necessarily expected that snow surveyors or the organizations that voluntarily perform much of the snow-survey work shall be responsible for improvement and maintenance of snow courses and facilities for snow surveyors, they may be looked to for suggestions regarding such matters and at times may find it convenient and desirable to lend a hand. That these ends may be accomplished it is desirable that the plan for action should be understood.

Safeguarding Desirable Features of Snow Courses

Logging and other avoidable operations that will impair or destroy a snow course or its markings should be guarded against. In the national forests and parks there is authority to stop such harmful acts, and elsewhere explanations may serve to deter them. The man on the ground is in best position to watch such matters and is called upon to do so.

Figure 5.—Permanent snow-course marker on a 2-inch iron pipe set in concrete.

Improving Ground Conditions for Snow Sampling

Maintaining and improving snow courses usually necessitate the removal of rock, down timber, brush, and an occasional tree. The ultimate aim is to provide a cleared 10-foot passage along courses or, at least, around each sampling point. If the ground surface is rocky or gravelly it may be desirable to replace it to a depth of an inch or so with stone-free soil in a 3-foot circle about each sampling point. Willows or other moutain brush can develop enough in one or two seasons to make their removal advisable, and during the late spring and summer erosion may occur or loose rocks and fallen trees may form obstructions on the snow course. Courses should therefore be inspected late in the fall of each year and at least a minimum amount of maintenance work performed.

Better Marking of Courses

Ultimately, or as funds become available for hiring the necessary labor, snow-course markers will be affixed to 2-inch iron pipes set vertically in concrete (fig. 5). In the meantime, present markings will be maintained by replacing defaced

markers and raising them on the trees or the posts to which they are now attached if experience shows they are not already high enough.

Making Trails Safer for Travel

The shortest route to snow courses is frequently across country. It is planned to chart these short cuts and make them safe for winter travel. Snow surveyors who have long snowshoe or ski trips to make are urged to consider such possibilities. Difficult trails should be signed with markers about 80 feet apart so that they can easily be found even when it is snowing.

Improving and Supplementing Shelter Cabins

To provide safety during winter storms and to afford rest, food, and lodging facilities regardless of weather, comfortable stopping places should be established for snow surveyors at half-day travel intervals, or approximately every 10 miles along the mountain routes they traverse on skis or snowshoes. Usually a cabin should be built near the base rather than at the top of a steep climb, because the

Figure 6.—Typical snow-survey shelter cabin under construction.

ascent can best be made after a rest, and if a storm should occur it may not be safe to attempt to cross divides. A flowing stream should be near at hand; otherwise quantities of snow must be melted to provide adequate water. The location must be free of any danger from snowslides, and the cabin site must be cleared of snags and leaning trees that might fall on the cabin.

Makeshift shelters are not sufficient. It is necessary that cabins be stoutly built so as to be comfortable places in which to live for several days if need be. They should be large enough to house a snow-survey party of two or more men. The roof must be strong to withstand heavy snow loads. It should overhang far enough to keep snow from blocking the access to the door and to provide a place for storing fuel (fig. 6). In a deep-snow country, where an ordinary cabin may

become completely hidden by snow, a deep-snow entrance tower (fig. 7) is required to afford a means of entry and exit. As an extra safety measure a pole should extend up from the entrance tower to mark the location of the cabin. Every precaution should be taken against attempts to burglarize the food and bedding within the cabin. The structure should be rodent proof. The usual one room should be tightly sealed to facilitate heating and the retention of warmth. A frostproof pit or similar storage place for food is required. Such facilities are often inadequate or lacking entirely, though the need for them is urgent.

FIGURE 7.—Shelter cabin with tower ("Santa Claus chimney") to permit entrance when the cabin is buried under deep snow.

EQUIPPING AND STOCKING SHELTER CABINS

A good heating and cooking stove, table, chairs, cots, and mattresses make up the necessary furnishings for shelter cabins. Before winter sets in there should be cached in each cabin dry fuel, food, bedding, and sundry other necessary articles. The following list of items is the requirement for two men for 15 days and is suggested as a basis for stocking the cabins:

Vienna sausage, 4 cans (small).
Bacon, 8 pounds.
Corned beef, 2 cans.
Roast beef, 4 cans (24 per case).
Beef stew, 2 cans.
Oysters, 2 cans.
Tomato juice, 12 No. 1 cans.
Peaches, 4 No. 2½ cans.
Pears, 2 No. 2½ cans.
Pineapple (broken slices), 2 No. 2½ cans.
Blackberries, 4 No. 2½ cans.
Soup, 6 cans (assorted).
Hominy, 3 No. 2½ cans.
Tomatoes, 4 No. 2½ cans.
Peas, 4 No. 2 cans.
Corn, 4 No. 2 cans.
String beans, 4 No. 2 cans.
Potatoes, 4 No. 2 cans.
Pork and beans, 4 16-ounce cans.
Dry beans, 2 quarts (in jars).
Rice, 2 quarts (in jars).
Prunes (dried), 1 quart (in jars).
Rolled oats, 1 quart (in jars).
Corn meal, 2 quarts (in jars).
Hotcake flour, 2 quarts (in jars).
Prepared biscuit flour, 4 quarts (in jars).
Cube sugar, 1 quart (in jars).
Sugar, 4 quarts (in jars).
Salt, 1 quart (in jars).
Pepper, 1 4-ounce can.

Vegetable shortening, 2 1-pound cans.
Butter, 2 1-pound cans.
Sirup, 1 can (small).
Preserves, 4 1-pound cans.
Brown bread, 2 cans (tall).
Oyster crackers, 2 quarts (in jars).
Milk, 12 cans (small).
Dried whole milk, 2 quarts (in jars).
Coffee, 2 1-pound jars.
Tea, 1 ¼-pound package.
Cocoa, 1 ½-pound box.
Chocolate, 1 pound.
Matches, 3 boxes (in jar).
Necessary cooking and eating utensils.
Dishpan.
Bucket.
Wash basin.
Can opener (cut-out).
Dish towels, 6.
Hand towels, 2.
Bath towels, 2.
Paper towels, 3 rolls.
Toilet paper, 1 roll.
Hand soap, 2 bars.
Laundry soap, 1 bar.
Scouring pads, 2.
Broom, 1.
Plumbers candles, 6.
Kerosene lantern, 1.
Kerosene, 5 gallons.
Shovel.
Ax.
A cheap but reliable alarm clock.
First-aid kit. (See p. 34.)
Sleeping bag and blanket for each lodger.
Snow-sampling equipment.
An extra length of stovepipe.

Bedding and similar articles should be hung by wires from rafters or otherwise protected from possible damage by rodents. All canned goods should be shellacked to prevent rusting, and all other food supplies should be in glass jars.

The shovel should be secreted under the eaves of the cabin or secured high in a nearby tree so as to be available to clear the cabin entrance.

The top of the stovepipe should be covered with a bucket or can to keep out snow. A ladder should be provided to reach the roof or entrance to the cabin. Old skis or snowshoes should be stored inside the cabin rather than thrown away.

Windows should be shuttered and the cabin otherwise made as secure as possible against unauthorized admission. Signs warning against trespass should be posted.

WINTER TRAVEL

To reach most snow courses during winter requires travel of a day or more on skis or snowshoes. This often imposes an extreme test of physical endurance and ability to withstand hardship. It is important, therefore, that the men who make these trips should be able to conserve their strength. To do so they must take advantage of the more favorable condition of travel and must have proper traveling equipment and know how to use it to best advantage. The experienced snow surveyor will choose the more roundabout or zigzag routes in preference to steep slopes and will get an early start while the snow crust is still firm (2:30 or 3 a. m.) if the condition of the snow during the day is unfavorable for traveling.

Selection and Use of Skis and Snowshoes [4]

Skis are by far the best and easiest method of travel if the person has had a little experience on them or is eager to learn to ski. However, under certain conditions, snowshoes (webs) would prove more satisfactory. For example, in mountainous country, for the person who is inexperienced in the use of skis or who is no longer a young

[4] This section was written by Alf Engin, advisor on winter sports, Forest Service.

man, showshoes will be easier and more comfortable method of travel. With snowshoes much more effort is required to cover the same distance than with skis and it takes almost as long to go downhill as to go up, but the sense of security gained by the inexperienced or the older man outweighs the faster and easier travel on skis.

Snowshoe bindings may be adjusted to fit almost any size of footgear and require no special boots. If much climbing is necessary, the snowshoe of the bear-paw type is the best. A fairly large size should be used because of the greater support it gives in loose, deep snow. If travel is to be in open, rolling country, a longer and narrower snowshoe may be used. Long, narrow snowshoes are not suitable in high, mountainous country, although a combination of the bear-paw and longer and narrower type may be used without any particular discomfort. In the early winter, when the snow is deep, a large snowshoe is much better; in the spring, when the snow is well-packed, a smaller snowshoe may be used.

Skis are the best method of snow travel, but the traveler must have some knowledge of their use or he will soon exhaust himself, particularly when going down steep hills. It would be advisable for the skier to have some instruction in the proper skiing technique before attempting a long trip in the mountains. However, if this is impracticable he can rope his skis going downhill as well as up, and in that way the inexperienced man may get downhill without any particular difficulty.

The man of average size should not use skis more than 7 feet long. A good rule to remember is that when the arm is extended upward, the ski should reach to the palm of the hand. A medium-width ski is best, and the extremely narrow type should not be selected. The slalom-touring ski has been found most suitable for all around use. Skis with flexible points and good spring about 18 inches back from the tip will not break so soon as the very stiff skis. Hickory is the best wood and will stand the most abuse.

A binding is necessary to fasten the foot to the ski. There are many types, but those that are easy to adjust to boots of different sizes are preferable. There are several makes that may be adjusted in a few moments by using a screw driver to turn a worm gear at the front and back of the toe iron. Once the binding is mounted to the ski it is a simple matter to adjust it to the toe of the ski boot. This is very important because proper control of the ski comes from the connection between the boot and the ski.

Two ski poles or sticks should be used and should reach, when standing on a floor, to the skier's arm pits, so that when they are in the snow they will give the forearm a level pull with the ground. Of course they may be longer or shorter without any particular discomfort. Poles of bamboo or tonken cane are not so expensive as those of steel. However, the steel pole requires less care and would probably last longer. The snow ring at the bottom of the pole should be strong and securely fastened.

It is imperative that a ski boot be used. The regular ski boot, which is low cut and allows free action in the ankles, is the only type of boot to use if one is doing much skiing. The boots should be protected by metal toe plates where they are fitted into the toe irons of the binding.

To permit climbing with a minimum of effort something should be used on the skis to keep them from slipping back. Wax may be used, but it must be skillfully applied. Most people use sealskins, plush, canvas sacks, or rope. Sealskins are the best but are expensive. By attaching plush or sealskins to the bottom of the skiis one can climb up hill, and can slide down without removing the skins. This is very handy while traveling over terraced country. On the descent the speed is cut to little more than walking pace, which is a great asset to the inexperienced skier. Canvas sacks that fit over the heel of the ski are convenient to use and are inexpensive. In an emergency, ordinary rope may be used. An 8-foot length of clothes line or similar rope may be doubled with a loop in the center and the loop placed over the tip of the ski. The rope is then crisscrossed on the top and bottom of the ski all the way back to the binding, where it is fastened to the toe iron. If attached to the ski in this way, the rope will give a good grip on the snow.

There are countless waxes for use on skis, but for the skis of a snow surveyor, on which something such as skins or rope is fastened to facilitate climbing, it is unnecessary to consider anything but a wax to prevent snow from sticking to the ski. Ordinary paraffin, ironed in with a warm flatiron or simply rubbed on cold, will do during the winter months. In the spring, when the snow is wet, a good coating of pine tar covered with paraffin rubbed on cold will make the skis slide freely. Many commercially manufactured waxes are obtainable, and the purpose and directions are printed on the containers.

A good pack sack will lessen the work on any trip. The surveyor should see that the shoulder straps are wide, that they come together and cross at the top of the pack, and that the weight lies on the hips. A strap may be used around the waist to keep the pack from rolling from side to side.

Suggestions on the Care of Snowshoes and Skis

The following further suggestions come from men who have done much winter traveling under conditions imposed by snow surveying:

For travel on hard crust, especially when descending and on sidehills, metal-edged skis are a distinct advantage.

To keep ski shoes in good condition and waterproof, the soles should be shellacked or covered with one of the preparations used for the running surface of skis. This keeps the sole hard and stiff. Most advertised greases should not be used because they tend to open the pores of leather, making shoes leak more than ever. Shoe wax thoroughly rubbed into the leather is better. If grease is applied it should be animal fats for vegetable-tanned leathers and some oil such as petrolatum for chrome-tanned leathers.

For keeping skis in good condition, hot linseed oil brushed on until no more is absorbed, or klister put on with a torch before they are put away gives excellent results.

After each trip, ski poles (cane) should be allowed to dry and should then be given a coating of spar varnish. They should be kept in a cool place to prevent checking or splitting.

Snowshoes are cared for in the same way as are cane ski poles.

Crew Requirements

It is expedient that a snow surveyor be neither expected nor allowed to undertake a winter trip into remote, unoccupied country unless accompanied by a fellow traveler who is competent to look after his own needs as well as to take his shift at trail breaking or packing emergency supplies and equipment and to render assistance to others in case of accident or danger. Fatigue, sudden sickness, or accident may befall even those who are able and experienced. It should not be assumed from previous good fortune that the way is safe for a lone traveler and that adversity will not overtake him sometime.

All members of a survey crew should use snowshoes or skis, and if skis are used all should be of the same width. This is desirable so that the different members may alternate in breaking trail effectively. If trail breaking is arduous or a heavy pack is carried, a prearranged relief schedule should be followed. Overwillingness or imposition in this respect is dangerous, because of the chance that an overworked individual may become exhausted.

Safety while traveling on treacherous snow requires that the two or more members of a survey follow each other at intervals, keeping within easy calling distance but far enough apart for the leader to give warning of danger ahead.

Dress

Clothing should be light and warm, but extra apparel adds unnecessarily to the weight carried and causes discomfort once the traveler is warm from exertion on skis or snowshoes. Light woolen garments are best. The following articles of dress are recommended:

Light woolen full-length underwear.
Light woolen shirt.
Long woolen trousers.
Two pairs of woolen socks.
Ski shoes (easy fitting).
Parka of pull-over type or parka and woolen stocking cap.
Heavy woolen mittens.
Dark smoked glasses.

Ski shoes should be large enough so that two pairs of heavy woolen socks may be worn; they may even be large enough to allow wearing three pairs. The surveyor should be sure that his boots do not fit too snugly, lest in extremely cold weather they induce frostbite by interfering with circulation.

A windproof parka is essential. A waterproof parka is good protection during wet snowstorms or spring rains. A dual-purpose parka, both windproof and waterproof, is not advisable, since the wearer will soon be wet from perspiration. In country where wet snow is to be expected, an oiled silk parka or sheet with a hole in the center for the head should be carried.

Dark smoked glasses should be worn in high altitudes when the ground is snow-covered, because under these conditions the glare from sunlight is particularly damaging to the eyes. Glasses that curve well around the outside corners of the eyes are recommended. If they are forgotten, broken, or lost it is helpful to blacken the face

beneath both eyes with charcoal from burned trees. Bark, pasteboard, or other material with narrow horizontal slits to see through, fitted into a broken pair of spectacles, or otherwise held, is the best substitute when sunlight is very bright.

Travel Kit

The emergency supplies and equipment carried should be restricted to a safe minimum. Usually they may be deposited about the person. All the following articles are considered useful at times, and the items in group 1 should be carried on all long trips:

GROUP 1

Amber goggles.
Two extra pairs of woolen socks.
One pair of woolen gloves to use while snow surveying.
Leather shoe dressing.
Ski wax (if skis are used).
Matches in small waterproof container.
Several candle stubs for kindling fires.
Lightweight hunting knife.
Small screw driver (if skis are used).
Extra leather thongs for ski bindings or snowshoes.

GROUP 2

Belt ax.
Side arm.
First-aid supplies (p. 34).
Small compass for use during storms when visibility is shut off.
Flashlight for night travel.
Light cotton rope 10 to 20 feet long.
"Snow surveyor's rag."

The amber goggles are for use in blizzards. The terrain may be seen much more clearly with them than with dark glasses when visibility is poor.

To prevent snow burn, a solution is recommended that can be made by dissolving 1 ounce of tannic acid powder in 3 ounces of alcohol and adding 1 tablespoon of glycerin. Apply this as a lotion before going out. It washes off readily.

A "snow surveyor's rag," a cloth about 2 feet wide and 5 feet long, slipped through the belt has many uses.

A small empty can on a thong serves as a drinking cup. This thong, tied to the end of a ski pole, will reach water at the bottom of a deep hole or in a snow-banked stream.

FIRST AID [5]

General Health and Advisability of Physical Examination

Likelihood of disability of members of the snow-survey party should be narrowed by medical examinations, serum treatments, and toughening exercises. A person with a weak heart, chronic appendicitis, varicose veins, or other physical weakness should not be per-

[5] For the following first-aid instructions to snow surveyors the author is chiefly indebted to Frank Tousic, first aid instructor, and F. X. Ammann, chief surgeon, Pacific Gas & Electric Co. (cooperator in snow surveys), and to Charles M. Fergusson, safety specialist, Office of the Secretary, U. S. Department of Agriculture.

mitted to participate. Cold serum should be given to surveyors if they have had pneumonia; and spotted fever serums, if there is danger of encountering ticks. It is well to arrange a few practice ski or snowshoe trips for the crew before they undertake a long journey to and from a snow course. Even with these precautions, there remain the chances of bone-breaking tumbles, excessive exposure, and unexpected illness. On the trail, doctors are beyond call, and snow surveyors should therefore be prepared to give expert first aid. They should also know how to administer remedies for at least the common ills. One member of each survey crew, if not more, should have had training in first aid; if he is an accredited first-aid man and has had the equivalent of the Red Cross first-aid course, so much the better.

It is highly desirable that a surveyor who goes into high altitudes to work under winter conditions have a physical examination, particularly of the heart, lungs, kidneys (urinalysis), and blood pressure. The rarefied atmosphere of the higher altitudes places a strain on the heart, which may become enlarged (athletic heart) or otherwise affected. Because of the increased acceleration of the heart induced by a limited supply of oxygen and the rapidity with which the oxygen is utilized by the tissues in zero or subzero temperatures, every precaution should be taken to avoid overexertion.

After the first stimulating effects of the cold air have subsided, a depression in the functions of the body cells takes place. It is more pronounced in the higher altitudes, and persons stimulated and exhilarated are prone to overexert themselves and so become fatigued. The first essential rule of living in high altitudes is: Be methodical, take time while walking and climbing, conserve energy, and eat moderately while engaged in active exercise.

Body heat is dissipated very rapidly in a rarefied atmosphere. This causes rapid chilling, with a resultant loss in bodily vigor and vitality and a consequent lessening of resistance to the disease-producing microbes that are ever present in the nose and throat. The second essential rule is: Wear warm, well-fitting, comfortable clothing. Wool is the ideal material for zero and subzero temperatures. The interstices of the loose-lying soft fibers create tiny air pockets that catch and retain the moisture and warmth generated by the body and permit slow dissipation of moisture and heat from the outer weather side of the material.

The third essential rule relates to bodily hygiene: Bathe frequently, drink plenty of pure water, maintain good elimination, eat moderately, vary the diet to include different vegetables and fruit juices, and obtain 8 hours of sleep a day.

First-Aid Kit and First-Aid Supplies

A complete first-aid kit or cabinet should be kept at an advantageous point. This kit should be completely equipped, and its stock should be checked at regular intervals. The following is suggested as the contents of a kit for a party of not more than 10 men.

1 first-aid book (Manual of First-Aid Instructions, issued by the United States Bureau of Mines, or First Aid Text Book, American Red Cross).
2 packages of compresses, 1-inch (Bandaids).
2 packages of compresses, 2-inch.

2 packages of compresses, 4-inch.
4 bandages, triangle.
1 package of inhalants, ammonia.
2 bandages, roller, 1-inch.
2 bandages, roller, 2-inch.
4 bandages, roller, 3-inch (for application of splints).
2 packages of gauze, sterilized.
1 package of cotton, 1 ounce.
1 thermometer, clinical.
1 1-ounce bottle of iodine, 3½ percent (for sprains and frostbite; should not be used in eyes, ears, and other passages to the inside of the body).
2 rolls of tape, adhesive, 1 inch by 2½ yards.
2 splints, arm (yucca wood or wire mesh).
2 splints, leg.
1 stretcher, army type.
2 blankets, wool.
Splint, back (material for knocking together).
1 roll of cotton, splint.
1 hot-water bottle.
1 ice bag.
1 syringe, fountain (for enemas).
100 5-grain Acetidin tablets (labeled "for use in colds, and for pain").
2 1-ounce bottles of castor oil (label specifying use in food poisoning).
2 1-ounce packages of Epsom salts.
1 8-ounce bottle of camphorated oil (for use in frostbite, sore muscles, congestion of chest).
1 2-ounce bottle of spirits of camphor (for use in frostbite).
100 tablets, indigestion (charcoal, pepsin, and soda).
4 ounces of boric acid powder (with directions for use as eyewash).
1 1-ounce bottle of aromatic spirits of ammonia (with direction for use as stimulant).
2 tubes of zinc oxide ointment (for use in skin irritation and galls).
2 5-ounce tubes of tannic acid jelly for large burns; and 1 package of 6 ½-ounce tubes of tannic acid jelly for small burns.
1 pair of scissors (6 inches).
1 pair of tweezers (splinter).
1 instant rubber tourniquet.
1 special burn kit (on general schedule of supplies) (includes tannic acid ointment).

Very few of the supplies listed above are perishable. Tincture of iodine and spirits of camphor will last for 6 months.

Surveyors working away from a base or shelter house in subzero weather should carry on their persons a small bottle of camphorated oil as a preventive against frostbite, a few ampules of ammonia inhalant, and some malt and chocolate tablets for use in exhaustion. A small first-aid packet containing essentials for emergency self-treatment may at some time be found an invaluable aid. A belt-type kit is recommended, since it is not likely to be left behind if for any reason the outer jacket and knapsack are left. In such a kit a limited number of standard, commonly used first-aid items should be included.

First-Aid Procedure in Certain Emergencies

FROSTBITE AND FREEZING

Frostbite, like burns, is of three degrees, depending on the temperature and the length of exposure. It is, in fact, a burn caused by cold. The first-degree frostbite is a chilblain, which appears as a redness of the skin. In a second-degree frostbite, blistering occurs. In third-degree frostbite, death (gangrene) of the tissues takes place.

A chilblain may disappear in a few days but may reappear on exposure.

Freezing first causes a sense of numbness of the affected part, which is followed later by complete loss of feeling. There is an early sense of prickling or tingling, as well as a condition of extreme paleness, and for a time a feeling of weight and coldness. When the affected part is warmed, there is extreme itching and burning, together with redness and swelling. The part frozen may have a spotted appearance.

The early recognition of frostbite or freezing is of great importance. Steps can be taken immediately to stop the action of further freezing on the affected tissues and to prevent the serious consequences of second- and third-degree frostbite, which may entail the amputation of a part.

Prevention of frostbite can be accomplished by protecting the extremities with proper clothing, such as woolen socks, waterproof boots, full-length woolen underclothing, mittens, a skull cap to protect the ears, and a woolen scarf or muffler to afford some protection for the nose. The cap should be selected with care. Some knitted caps are too porous and afford very little protection from cold, especially if a strong wind is blowing. A good fur cap is best; however, if it is necessary to use a woolen cap, an outer covering of felt or other close-woven material will be found to increase the effectiveness of the wool. A hunter's mitten of lined leather with a woolen glove worn inside is also recommended, since it is more comfortable than the single woolen mitten and permits the use of the fingers and hand to better advantage.

Care should be taken that the circulation be not impaired in the extremities through constriction of clothing. Boots should not be laced too tight, wrist bands should be loose and comfortable. Wet socks and mittens or gloves should be removed and replaced with dry ones as soon as possible. It is good policy to carry extra socks and gloves in waterproof covering on long trips.

When the first symptoms of frostbite appear, warmth in one form or another should be applied. The heat of the bare hand, withdrawn from a warm glove or mitten, will soon thaw a small frost-bitten spot on the face or elsewhere on the body. Lukewarm (not hot) water (if available) may be rubbed on the affected part; or a warmth-producing solution such as spirits of camphor or camphorated oil can be applied. Friction with the oil not only stimulates the circulation of the outer skin but also forms a protective film, which helps to retain the created heat. At no time should the affected part be brought near heat until normal circulation has been established. After circulation has been restored to normal, the part may be painted with tincture of iodine. Care should be taken not to paint too large an area. The iodine should be allowed to dry before the affected part is bandaged or clothing replaced.

In severe frostbite, gentle friction with water slightly below body temperature will be found effective. If the patient is indoors, the room should be cold. As the circulation returns to normal, the temperature of the room should be gradually raised. Hot stimulating drinks, such as coffee, tea, milk, or warm broth should be given. If blistering or signs of gangrene become apparent, the patient should be brought under the care of a doctor as soon as possible.

Freezing may affect the entire body, and prolonged exposure may result in a sensation of drowsiness and numbness. The skin is pale, since the blood is driven into the internal organs. Deep sleep results, the pulse becomes slow, respiration becomes slow and is accompanied by snoring. The body becomes cold and, unless the victim is rescued, death results. In treating a case of this nature, the first objective is to stimulate and conserve body heat. This can best be accomplished by the administration of 1 teaspoonful of aromatic spirits of ammonia in hot or warm water. Hot coffee is also a good stimulant and may be used before or after the aromatic spirits of ammonia. The patient should then be taken to a sheltered spot and gentle friction created over his entire body, which should be kept covered by clothing or blankets. If the patient is in a stupor from which he cannot be aroused inhalations of aromatic spirits of ammonia should be given to stimulate heart and respiratory action.

If a rescue party has found the sufferer, members of the party should at once build a fire, and as circulation and body temperature is restored, the patient may be slowly moved closer to the fire and friction should be gradually increased. Hot drinks should be given freely. If life appears to be extinct in a frozen person, artificial respiration should immediately be resorted to. An assistant should start friction treatment immediately. Artificial respiration should be kept up for at least 1 hour. Cases are on record where success was finally attained hours after apparent death.

SUNBURN

Sunburn is caused by exposure to the rays of the sun. As this form of burn is produced by the ultraviolet rays, it may occur on a cloudy day as a result of the rays that filter through the clouds. Often persons not aware of the danger received severe burns from prolonged exposure on cloudy days. Sunburn is usually a first- or second-degree burn and, if a large surface of the body is exposed, may cause severe illness and fever. When this occurs, the patient should be placed under the care of a physician as soon as possible. Sunburn can be prevented by gradually building up a good coat of tan through exposure to the sun several minutes each day. Application of olive oil, cocoa butter, or some good burn ointment is of considerable help in the prevention of serious burns. Petrolatum or other greasy preparations should not be applied to the skin after it has been burned, since they prevent the effective use of the proper burn treatment, such as tannic acid. The tannic acid treatment has been adopted by both the Civilian Conservation Corps and the Department of Agriculture as first aid for burns of all kinds. The best protection for the upper body during exposure is a shirt. The treatment of sunburn depends on its severity, but is similar to the treatment for any other first- or second-degree burn.

In treating a first-degree sunburn, which appears as a reddening of the skin but not blistering (the skin is lobster red and hot to the touch), exclusion of air and the application of a bland oil to relieve discomfort is about all that is necessary.

In treating sunburn of the second degree, in which more or less excessive blistering is present, air should be excluded as quickly as

possible. The choice of treatment depends on whether the blisters are broken. If they are unbroken, the injury should be treated as a first-degree burn. If they are broken, they should be treated as an open wound. Owing to the presence of destroyed and devitalized tissue, infection may occur. A burn of this nature should be kept very clean, and clothing should be kept from contact with the burned area.

If a large area of the body is burned, a state of bodily poisoning may exist owing to the inability of the body to throw off the accumulated poisons the normal skin would excrete and to the absorption of poisons from the devitalized tissues. This condition is evidenced by feverishness. It may become serious, and a case of this nature should be brought to the attention of a physician as soon as possible.

The treatment of second-degree sunburn that has blistered is most effective with a tannic acid spray outfit. The blisters, particularly those on the patient's back, may be punctured at the base and the liquid allowed to escape slowly as the tannic acid spray is applied. The danger of infection is not great with this treatment because the water with which the tannic acid is mixed contains a small amount of merthiolate, which can be relied on to take care of any ordinary infection that may be present.

A special burn kit for use in remote areas is being placed on the general schedule of supplies. This kit is designed for the first-aid treatment of large burns. In fact, it contains sufficient materials to treat a burn of any size. Tannic acid ointment or jelly can best be used by spreading it over a large bandage, which is then applied directly to the burned area. Care should be taken to keep the dressing sterile. Baking soda, in addition to being very painful, is not nearly so effective as tannic acid. If the blisters are on the patient's back they should be carefully drained before or after the tannic acid treatment, since they are nearly always broken by the patient's thrashing about or turning on his back.

The use of a tannic acid spray prevents the direct absorption of the albumen into the blood stream. The cooling effect of the water solution as it is applied, as well as the cooling effect of the evaporation of the water, is an advantage. This spray has also the advantage of being equally effective when used either with or without bandaging. It is not necessary to remove pieces of underclothing that may adhere to the burned skin, since the spray will penetrate and be effective anyhow. Another benefit is that the spray may be applied without removal of the bandage.

CRAMP

A cramp is a spontaneous contraction attributable to a number of causes, chiefly fatigue, a chill, or irritation of the muscular cells from an internal poison. The most common type of cramp is one that affects the calf of the leg and other long muscles of the extremities or one of the stomach and intestines. Stomach and intestinal cramps are sometimes caused by heat and the exhaustion of the salt content of the body through perspiration and the emission of urine. For correction of such conditions the first-aid kit should contain small quantities of 10-grain salt tablets, as a precaution against shortage of salt in the grocery supplies.

A cramp of one of the large muscle groups of the extremities is frequently called a Charley horse. The affected muscle or muscles contract and form a hard, rounded mass; the pain is severe and sharp. The part can be straightened out only with difficulty. The treatment consists of warmth and massage. A hot-water bottle, pad, or heated object should be placed over the muscle, care being taken that the object is well wrapped to prevent burning of the skin. The cramped part should be gently massaged with camphorated oil or with a liniment. Immersing the part in hot water and massaging will relieve the cramp. If cramps of this nature persist, a physician should be consulted, since they may be an indication of a systemic disorder. After a severe muscular cramp, the part should be rested by slightly elevating the affected member until complete relaxation has taken place.

A cramp of the stomach is usually caused by some indiscretion in diet. The drinking of ice water while the affected person is in an exhausted or partly exhausted state is a common cause. The cramp may be a symptom of impending food poisoning. A cramp of this nature generally comes on suddenly and may be severe enough to cause faintness and a desire to vomit (nausea). It is high in the abdomen, just under the breastbone, and if severe may cause painful contraction of the upper abdominal muscles. The first-aid treatment consists of applying heat to the region of the cramp after the patient has been put to bed. Several glasses of warm water containing 1 tablespoonful of salt to the glass or plain warm water should be given; this, followed by sticking the finger down into the throat or tickling the throat with a feather, will induce vomiting, which will relieve the stomach of the irritating substance. If there does not appear to be any fever and the pulse is normal, 1 tablespoonful of castor oil (for an adult) may be given in some hot weak coffee to clean out any of the irritating bulk that got into the intestines. It should be remembered that keeping heat to the area of the stomach is of utmost importance as a first-aid measure. If the cramps do not respond to treatment and fever is present, efforts should be made to obtain medical aid. If medical aid cannot be obtained, 1 teaspoonful of paregoric may be given at 2-hour intervals. It should be diluted with water.

Intestinal cramps are generally intermittent and are most often caused by a foreign irritating mass in the intestines. They are usually the forerunner of a diarrhea (running off from the bowels); these cramps appear lower down in the abdomen than stomach cramps. The treatment consists of the application of heat to the abdomen, and if no feverishness is present and the pain does not seem to be localized on the right side, 1 tablespoonful of castor oil may be given.

The administration of a cathartic in cases of stomach and abdominal cramps should always be considered with caution because of the chance of a mild appendix irritation flaring up into an acute condition. "C.C." (compound cathartic) and other drastic purgative pills, on account of their direct irritant action on the delicate intestinal lining, should not be given.

The stomach and intestines should be permitted to rest for at least 8 hours after a severe attack of cramps. Light semisolid foods

should then be given. Prepared milk, hot gruel, soft-boiled eggs, clear bouillon with toast, and orange juice mixed with the beaten white of an egg are suggested.

EXHAUSTION

Exhaustion is a condition brought on by loss of vital and nervous power due to fatigue or lingering illness. It is closely allied to shock, and utter exhaustion may become a serious problem demanding immediate attention to prevent complications, the most serious of which are pneumonia and heart failure in those individuals suffering from a heart complaint. The symptoms are very similar to those of shock, and the treatment is the same with the exception that the patient should be kept off his feet, in bed, under stimulative treatment (1 teaspoonful aromatic spirits of ammonia in 1 glass of water) until bodily strength and vigor are restored. Light, easily digestible, nourishing foods should be given. Chicken and beef broth, raw or soft-boiled eggs, clam broth, or cocoa may be given the first day. More substantial foods may be given as vigor returns and strength increases. Fruit juices are very beneficial and should be given freely.

SHOCK

Shock is a profound impression made on the nervous system. Traumatic shock occurs to a more or less degree after all accidents. It can also be caused by fright, anger, or other psychological condition. Surgical shock generally follows an operation; the patient is prepared for the shock before entering the operating room. Fainting is a mild form of shock.

Shock is dangerous and should be given immediate attention. Most fatalities occur, not from the injury, but from the resulting shock. In shock, the profound injury to the nervous system paralyzes the system temporarily, causing the blood vessels to lose their tone. The blood then stagnates in the large vessels in the abdomen; and the brain, deprived of its normal supply of blood and nutrition, becomes anemic. Complete lapse of many functions results, and, in severe cases, death of the nerve tissue, which means cessation of life in the patient.

Allowing a patient to see his own injuries often causes shock, especially if there is severe bleeding. When a patient is suffering from shock, his face is pale; he has an anxious expression; his eyelids droop; his eyes are dull and the pupils large; his skin is clammy and covered with a cold sweat; he is somewhat stupid and takes little interest in what goes on about him. He may suffer from nausea and vomiting. He may answer questions slowly. He may be partly or wholly unconscious, or his mind may wander. Usually the patient is perfectly quiet and will not move unless disturbed. Breathing is shallow and feeble; the pulse is weak and rapid and may not be felt at the wrist. When this condition is observed, medical aid should be obtained as soon as possible.

In ordinary fainting, due to emotional or slight traumatic causes, the mild shock may be averted while the patient is in a seated position by putting his head down low between his knees. In severe shock

he should be placed in a comfortable position, with head low unless there is a fracture of the skull or severe bleeding from the head. All foreign bodies, such as false teeth, tobacco, and gum should be removed from the mouth. The body should be wrapped in warm blankets or clothing, after tight clothing, such as neckband, belt, and boots have been loosened. If the patient is conscious, aromatic spirits of ammonia (1 teaspoonful in one-half glass of water) should be given slowly, so that the patient will not choke. Hot coffee, hot tea, or hot water is beneficial. If the patient is unconscious, he should not be given anything by the mouth. Aromatic spirits on a cloth or broken inhalant should be placed under his nose. Hot-water bottles, hot bricks, or hot plates should be put around him, under the covering; they should be wrapped in cloth or paper to prevent burns. As an unconscious patient cannot make it known that he is being burned, great care should be taken. The patient's arms and legs should be massaged toward the heart, but he should not be uncovered. A light hot-water bottle, well wrapped in cloth or paper and placed over the heart is a good stimulant.

Although shock is dangerous and commonly follows injuries, it must not be forgotten that the patient may require treatment for something still more dangerous; for instance, severe bleeding, which must be checked.

SNOW BLINDNESS

Snow blindness is an intolerance to light and inflammation of the outer tissues of and around the eyeball. It is caused by the reflection of the sun on the white snow, through the medium of ultraviolet and other injurious concentrated light rays reflected into the eye, the injury coming from burning and irritation of the delicate eye membranes. The same effect would be produced by looking directly into the bright sun or long and intently on white clouds. In either case, there is damage to the retina, which contains millions of delicate sight cells. The eye becomes sunburned.

There is considerable redness and pain in the eyeball, which may be accompanied by swelling of the lids and a serumlike discharge. The resulting blindness is transitory, and vision returns after a length of time that depends on the amount of exposure.

As a prophylaxis against snow blindness, tinted lenses may be worn. All lenses should be optically correct and hand ground. Persons habitually wearing glasses for the correction of astigmatism, nearsightedness, or farsightedness might find it advantageous to have their prescription ground into the tinted lenses. Glasses of the goggle type are the most efficient, if they have holes or slots to permit free ventilation and prevent moisture from collecting on the lenses. A composition frame, which conducts heat less readily than a metal frame, will be found more comfortable.

The first-aid treatment for snow blindness consists of the application of cold compresses to relieve pain and inflammation and the instillation of a few drops of a bland oil, such as olive or castor oil, into each eye at ½-hour intervals. The affected person should be placed for several days in a room from which all light has been excluded. If the pain and inflammation are very severe and do not respond to treatment, medical attention should be secured as soon as possible.

SPRAINS

A sprain is an injury of a joint. It results from violent twisting, or stretching, or partial breaking of ligaments about a joint. Sprains may be described as temporary dislocations; that is, the joint becomes momentarily dislocated, but immediately thereafter slips back into place. The wrists and ankles are the joints most frequently sprained. The symptoms are: Pain, often very severe, at the joint at the time of injury; swelling over the joint, which takes place very rapidly owing to the blood's being poured into the surrounding tissues from the ruptured capillaries and small blood vessels; inability to use the joint without increasing pain; and discoloration, which, though not apparent immediately, may last for weeks after it appears. Usually it is not difficult to distinguish between a sprain and a dislocation, but it is often very difficult to tell the difference between a sprain and a fracture at a joint. These two conditions may occur together. Where there is doubt, the treatment should be for fracture. Sprains vary a great deal in severity, from a minor one lasting just a few minutes to a severe one in which the ligaments are torn and much blood has oozed out into the surrounding tissues. Such sprains require weeks for complete healing to take place.

The first-aid treatment for sprains consists of elevating the injured joint and putting it at complete rest. A sprained wrist should be rested by means of a sling; an ankle, by having the patient lie with ankle elevated by means of a pillow or coat. There is always danger that a fracture may be associated with a sprain. Cold applications usually are the best. They allay pain and relieve the congestion in the part. In severe cases of sprain if shock is present, it would be more advisable to use hot compresses or heat in other form. Cold may be applied for a few hours by means of bags filled with ice or compresses wrung out in cold water or by holding the injured member under cold running tap water. In severe sprains, a cravat bandage should be applied to the injured joint and the patient should be seen by a doctor. When it is absolutely necessary for a person with a sprained ankle to walk some distance for aid, a tight cravat bandage should be placed around the ankle without removing the shoe.

If a knee is sprained while the surveyor is on the trail, the knee may be mobilized by the application of a cravat bandage tied fairly tight over the clothing. If the sprain is at all severe and the injured person cannot walk to shelter, he should be carried. If this is not possible, two splints extending half way up the thigh and half way down the calf of the leg should be applied over the clothing of the injured member. This will form sufficient support, so that with some assistance a certain amount of weight may be placed on the injured member.

RUPTURE

A severe rupture may occur about the navel or any part of the abdominal wall; however, the largest percentage of ruptures occur in the groin and are caused by a strain that forces the intestinal covering or the intestines themselves through the triangular ring formed by the muscles in the groin, through which the arteries, veins, nerves, and spermatic cord pass into the sac that contains the

testicles. This is the type of rupture that will require first aid most frequently. A lump containing the intestine or covering of the bowel will appear in the groin. There will be sharp, stinging pain, a faint feeling, nausea (a sickness in the stomach), a feeling that something has given away, as the lump appears and the intestines are forced through the abdominal walls. A rupture must be handled with care and gentleness. Rough handling may lead to serious injury; it may strangulate the rupture (that is, enough of the intestine may be forced out of the opening to cause a constriction around the base of the lump from the pressure of the separated muscle) and thus cause gangrene of the intestine, or at least inflammation.

For treatment, the patient should be placed on his back with knees well raised toward the abdomen; the legs should be supported by a pillow or folded jacket. Cold wet compresses should be applied to the lump. The hips should be raised to permit the intestine to slip back into the abdominal cavity. Under treatment, the lump may disappear, owing to the slipping back of the contents, but this disappearance does not mean that the trouble is over. Under no circumstances should the patient be permitted to get to his feet. A doctor should be called immediately. If the patient has to be moved, he should be kept in the position described above.

APPENDICITIS

Appendicitis is the inflammation of a small intestinal appendage attached to the large intestine near its juncture with the small intestine. It is a small blind sac ordinarily situated at a point midway between the navel and crest of the hipbone. Because it is a blind sac, permitting no drainage, foreign material lodged in it may cause heat and irritation and more or less inflammation, which may become so serious as to necessitate an operation. A physician or trained medical attendant may often find it difficult to recognize this infection, and a layman would become utterly confused in attempting to make a diagnosis.

Briefly, the cardinal symptoms of appendicitis, in accordance with severity, range from a mild localized pain in the lower right side, to sharp excruciating pain, accompanied by fever and vomiting. In an acute attack, the sufferer lies with knees drawn up and the muscles of the abdomen on the right side are hard and cramped.

The first-aid treatment consists of immediate rest in bed. The head of the bed should be slightly raised. A person stricken with an acute attack of appendicitis while on the road will stoop toward the right. The sufferer should not be permitted to walk but should be carried to shelter. Nothing, not even water, should be given by the mouth. Under no circumstances should a cathartic or laxative be given, as it may flare a passing irritation into an acute condition and thereby endanger the life of the patient. An ice bag or iced compresses should be applied continuously to the lower abdomen over the appendix area. When the symptoms abate and the pain has disappeared under gentle pressure, fruit juices in small quantities may be given, as may also bouillon or milk. If the patient is constipated, an enema may be given. Solid food may be given 12 hours after the symptoms have subsided. If the fever is very apparent and the pain

intense, especially if accompanied by vomiting, and if the symptoms do not subside, medical attention should be secured as quickly as possible, for an immediate operation may be necessary.

PNEUMONIA

Pneumonia is an acute inflammation and congestion of the lungs. There are several varieties. The lobar type (infecting the lobes of the lung) is most common. The infection is caused by a specific germ. The condition may come on very suddenly, especially in individuals who are exhausted. The onset of the disease is a chill, followed by a rapidly rising fever; there is pain in the chest and a heavy congested feeling. The respiration becomes fast and shallow at a rate of about 30 to 45 a minute; the pulse becomes fast. A tight, raspy cough develops, and a rusty colored sputum is brought up.

An early recognition of the symptoms is important. The congestion of lung tissue cuts down the area available for the distribution of oxygen to the blood cells, and to overcome this defect a great strain is thrown on the heart, whose action is greatly accelerated to step the circulation up to a faster pace.

The important point to be remembered in first aid for pneumonia is that efforts of the laboring heart must be eased and its energy conserved. Upon the appearance of symptoms of pneumonia the affected person should be well wrapped in blankets and carried, if possible in a recumbent position, to a shelter. He should be undressed and put to bed, and after a liberal application of camphorated oil, his chest should be well wrapped with flannel or woolen material. The room or shelter should be well ventilated, with plenty of fresh, cold air, but without a direct draft on the patient. Warm, prepared milk containing ½ teaspoonful of aromatic spirits of ammonia should be given every 2 hours. The patient should not be permitted on his feet under any circumstances, but should be kept quiet. The head of the bed may be slightly raised. Medical attention should be secured as soon as possible.

PULSE AND TEMPERATURE

Men on snow-survey work should know how to read a clinical thermometer and take a pulse. The pulse should be taken at the wrist on the thumb side by placing the index and midfinger at a point about one-half inch in and making gentle pressure. The normal pulse ranges from about 68 to 80 beats per minute. Normal temperature is 98.6° F.

CONCLUSION

In making snow surveys it has been possible to avoid the usual difficulties and uncertainties of organizing and holding a force for seasonal and intermittent work by obtaining the aid of organizations having regular employees competent to carry on the surveys and conveniently stationed to do the work.

Surveyors can build up a background of information that extends beyond the measurements they take and record in making a survey. The surveyors have the opportunity to gain by observations made on the trips some knowledge of the individual peculiarities of each drain-

age basin, a knowledge essential to water-supply forecasting. Local conditions and needs afford special opportunities for using the snow-cover data. The workers who are on the ground are in the best position to appraise these conditions and needs and to become contributors to the extension and improvement of the service. Many seasoned snow surveyors are now recognized authorities on water-supply forecasting in their districts.

The success achieved in snow surveying is due largely to the precautions always taken to insure that incoming cooperators appreciate the uses to which the snow-survey data can be put and understand the fundamental principles of snow surveying. This publication provides some of the needed information. It gives detailed instructions for that part of the work performed by the snow surveyor and makes suggestions for winter travel. It also touches upon the purposes served by snow surveys and the general principles of water-supply forecasting.

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